Identification and Characterization of Populations Living Near High-Voltage Transmission Lines: A Pilot Study

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Populations living close to high-voltage transmission lines often have residential magnetic field exposures in excess of 1 μT, and sometimes over 2 μT. Yet, populations studied in most epidemiologic investigations of the association between residential magnetic field exposure and cancer typically have exposures below 1 μT and frequently below 0.5 μT. To improve statistical power and precision, it would be useful to compare high exposure populations with low exposure populations rather than only studying small differences within low exposure populations. Toward this end, we have developed an automated method for identifying populations living near high-voltage transmission lines. These populations likely have more highly exposed individuals than the population at large. The method uses a geographic information system (GIS) to superimpose digitized transmission line locations on U.S. Census block location data and then extract relevant demographic data. Analysis of data from a pilot study of the populations residing within 100 m of a 29-km segment of one 230-kV line in New Jersey shows that when compared to populations in the surrounding census blocks farther than 100 m from this line, those populations close to the line have similar demographics but differ in terms of perceived housing value variables. We believe that the approach we have developed will enable investigators to rapidly identify and characterize populations living near high-voltage transmission lines on a statewide basis for considering the impact of exposures and for public policy and that these populations also can be used for epidemiologic study. *Key words:* electromagnetic fields, geographic information system, high-voltage transmission lines, population identification. *Environ Health Perspect* 101:626–632(1993)

Exposure to electric and magnetic fields has become a major area of research and concern over the past 10–15 years. With the publication by Wertheimer and Leeper of the seminal paper investigating the association between residential exposure to electric and magnetic fields and the incidence of childhood cancers in Denver, Colorado (*1*), there has been an explosion of concern by the press and the public and expanding study by the scientific community (*2*). Studies designed to replicate this seminal study in Denver and elsewhere (*3–10*) have had mixed results, generally finding associations between indicators of magnetic field exposures and cancer more often than not. Overall, in residential studies, elevated magnetic fields but not electric fields have been associated with excess cancer.

A complementary approach used to investigate the association between electric and magnetic fields and cancer has been the study of mortality patterns of workers with high occupational exposure to electric and magnetic fields. The excess rates of leukemia and brain cancer deaths observed in these studies [e.g., Theriault (*11*)] have substantiated concern about exposure to electric and magnetic fields. But because the actual magnitude of electric and magnetic field exposures has not been documented in these occupational studies (exposure estimates for most such studies are based on job titles) and because these workers may be exposed to other hazardous substances while on the job (leading to confounding), these studies are not considered conclusive.

One important observation about the residential studies is that, due to epidemiologic design characteristics, most exposures cited have been fairly low, nearly all below 1 μT (= 10 mG) and most below 0.5 μT (= 5 mG). However, numerous homes have exposures as high as 2 μT or more, and the principal source of this exposure is most often ascribed to proximity to high-voltage transmission lines. Further, prediction of the magnetic fields attributable to proximity to high-voltage transmission lines is far easier and more accurate than prediction of fields generated from other sources.

The goal of this study was to develop methodology to identify populations that are exposed to electric and magnetic fields from overhead high-voltage transmission lines. This will enable us to determine the number of exposed people and characterize their demographic attributes for risk assessment and public policy considerations. In addition, if sufficiently accurate, this method could be used to determine the incremental exposure to electric and magnetic fields that populations incur from high-voltage transmission lines, a possible exposure metric for use in epidemiologic investigations of excess cancer. By focusing on these highly exposed populations, we believe we would increase both the statistical power and precision of epidemiologic investigations.

We know of only two studies that previously attempted to identify and/or characterize populations residing near high-voltage transmission lines. Florig and Morgan (*12*) assessed the density of housing along transmission lines by reviewing aerial photographs. They found that the population density close to the lines was lower than elsewhere in the region and that the difference in density decreased as the distance of the residences from the line increased up to 200 m, the maximum distance they report. Salzberg et al. (*13*), in Melbourne, Australia, investigated the association of ambient magnetic fields with various indices of socioeconomic status. Using an arbitrary sampling grid in which 77% of the sampling locations were under overhead transmission or distribution lines, they found only weak associations between the strength of the magnetic field and specific aspects of socioeconomic status, and none with combined indices of socioeconomic status variables. They concluded that there was no overall association (*13*). While other epidemiologic investigators have considered transmission lines as confounders (i.e., factors associated with both exposure and disease, although not of primary interest), they generally have not analyzed demographic data with respect to these lines (*1,3–10*).

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In Scandinavia, it is possible to identify populations living near high-voltage transmission lines using public records. These records, which are far more detailed and/or accessible than those available in the United States, include cancer registries, population registries (which contain complete residence histories), and utility transmission line databases. Using these data to derive separate exposure estimates based on distance from the transmission line, current magnetic field strength, and reconstructed historical magnetic fields strengths (using historical annual average load data for each year of residence), epidemiologic studies have been conducted in Sweden (*14*), Denmark (*15*), and Finland (*16*). Although these studies evaluated the association of estimated magnetic field exposure with disease incidence, they did not look at indicators of socioeconomic status.

To demonstrate the feasibility of conducting an epidemiologic study in the United States using highly exposed populations, we chose to identify populations living within a few hundred meters of high-voltage transmission lines. To get a sufficient number of such individuals, it may be necessary to include hundreds of miles of such lines. Although high exposure populations could be identified using aerial photographs, it would be extremely time consuming and labor intensive. Our approach is to use a computer-based geographic information system (GIS) to combine independently developed transmission line location data with the most recent (1990) U.S. Census data to identify and characterize such populations. In addition, address ranges can be extracted for record matching with disease registries and for contacting individuals.

To demonstrate our approach, we have undertaken the pilot study reported here. To demonstrate that this approach will generate sufficient number of subjects at the appropriate scale of geographic resolution, a larger study would be needed. We plan to begin such a study to identify all populations living near 230-kV and higher voltage lines in New York State in fall 1993 in cooperation the Empire State Electric Energy Corporation.

Background: Electric and Magnetic Fields and Cancer

In general, measuring and assessing exposure to electric and magnetic fields have been problematic in epidemiologic studies. Growing concern about a relationship between electric and magnetic fields and cancer is driving research to improve exposure assessment. Investigators have estimated residential exposure in a variety of ways, basing exposure on proximity to high-voltage transmission lines, the configuration of electrical wiring outside each residence (i.e., the so-called wire codes), spot measurements of magnetic fields, 24-hr measurements of magnetic fields, and historical reconstruction of cumulative magnetic fields based on line load data. However, the consistency among these measures has been less than desired for epidemiologic studies. The goal of most exposure studies has been to capture relevant aspects of the hourly, daily, seasonal, and secular patterns of variation while accommodating historical changes in electric power delivery. However, because there is no known mechanism of disease causation from exposure to nonionizing radiation, it is not clear what aspects of exposure are biologically relevant. In occupational studies, job titles have been used to classify exposures, which likely results in much imprecision and substantial confounding. Kaune (*17*), in a recent review, notes that there are also many limitations to the spot measurement technique used in some residential studies, including short-term variability, spatial variability, and selection of a metric for time averaging.

One noteworthy observation is that homes near high-voltage transmission lines often receive a substantial but variable portion of their magnetic field exposure from those lines (Table 1). For example, Caola et al. (*18*) measured electric and magnetic fields in three New Jersey homes and found that electric fields produced by the house wiring were similar to those produced by the transmission lines, with shielding of external fields provided by walls without windows, while magnetic fields inside the houses were not affected by the walls (i.e., there was little shielding) and were about 0.25 μT. Maddock et al. (*19*) discuss the magnitude of electric and magnetic fields under high-voltage transmission lines in the United Kingdom and state that for a 400 kV line, electric fields at 25 m from the center line are less than 1 kV/m, whereas magnetic fields at 25 m rarely exceed 10 μT. Stuchly (*20*) reports calculated maximum magnetic fields of 13 μT at the center line for a 230-kV line, 33 μT for a 500-kV line, and 29 μT for a 765-kV line. Residential measurements, she reports, range from typical backgrounds of less than 0.1 μT to levels over 0.5 μT for houses with electric heaters. Levels for homes in Germany were substantially higher (*20*).

Heroux (*21*) investigated ambient, urban electric, and magnetic fields resulting from electric distribution lines between 49 kV and 735 kV and found magnetic fields generally below 1 μT and electric fields generally below 0.3 kV/m. Dlugosz et al. (*22*), reporting magnetic field measurements made at 33 street corners in Buffalo, New York, found flux densities as high as 1.6 μT. Three street corners had transmission lines within 46 m, and these were the three highest mean flux densities (1.08–1.44 μT).

Bracken (*23*) summarized exposures in public access areas by noting that both electric and magnetic field exposures are related to the proximity of transmission and distribution systems and, while generally similar to residential exposures, can be as high as 180 V/m and 10 μT. Commercial buildings, however, likely have different electric shielding properties. Kavet et al. (*24*) studied 45 adult residents in Maine and found that, for the 30 who lived near high-voltage transmission lines, the transmission lines were a significant source of exposure (more than 50% of the total exposure) and that in-home measurements were a reliable index of total exposure ranging from about 0.5 μT to 6 μT.

Proximity to Transmission Lines as an Exposure Metric

As homes with unusually high magnetic fields (e.g., greater than 1 μT) generally are close to high-voltage transmission lines, if there is an association between high magnetic fields and cancer incidence, residents of these homes should be at greatest risk. Yet, only a few epidemiological studies have emphasized the role of transmission lines in elevating exposures.

Table 1. Exposures near high-voltage transmission lines

Source of exposure	Magnetic field (μT)	Electric field (kV/m)	Reference
Homes near transmission lines	0.25		(*18*)
400-kV line			(*19*)
Center line	<40	<5	
25 m	<10	<1	
Center line			(*20*)
230-kV line	13		
500-kV line	33		
765-kV line	29		
Residence	0.1-0.5		
49-kV–735-kV urban line	<1	<0.3	(*21*)
33 Buffalo, NY street corners	<1.6		(*22*)
Residences	<10	<0.18	(*23*)
Homes 79 m–465 m from 345-kV line	0.08–0.58		(*24*)

Myers et al. (*6,7*) studied children living near overhead electric lines in Yorkshire, England, and did not find a significant association between distance of residence from overhead line or calculated magnetic field (based on maximum load during year of birth) and the incidence of childhood cancer. However, critics have pointed out that only 5 out of 962 subjects had exposures above 0.1 μT, suggesting unusually low exposures overall. McDowall (*25*) investigated the mortality experienced by persons living near electric transmission facilities in East Anglia, England, and found lower than expected mortality in the study population, with only female lung cancer being statistically significantly elevated. (The lung cancer observation was hard to interpret because the investigators did not have data on smoking habits.)

Tomenius (*8*), in a case–control study in Sweden, found that those living in proximity (within 150 m) to a 200-kV electric transmission line were at excess risk of cancer [relative risk (RR) of 2.1]. Coleman et al. (*26*) investigated the association between leukemia incidence and proximity to electricity transmission equipment in Southeast England and found elevated but not statistically significant effects (RR of 1.5 for residence within 100 m of an overhead transmission line, RR of 2.0 within 50 m). Johnson et al. (*27*) conducted a spatial analysis of leukemia and brain cancer incidences and transmission line location. Although the disease incidence patterns exhibited a nonrandom pattern, they found no association with transmission line location. Schreiber et al. (*28*) studied the mortality experience of the population living near two 150-kV lines and one transformer substation. They also did not find significant elevations of cancer mortality rates.

Most recently, a series of nested case–control studies has been conducted in Scandinavia. These studies used a variety of exposure metrics including measured distance to transmission lines, measured magnetic fields, and computed exposures attributable to electrical transmission connections and substations based on historical line loads and tower configurations. Feychting and Ahlbom (*14*) conducted a residential study among people living near high-voltage transmission lines. Elevated cancer rates were observed within 300 m of these lines [odds ratios (ORs) generally from 2 to 5 for leukemia for calculated magnetic fields]. When analyzed similarly, these data gave relative risks comparable to those of Savitz et al. (*9*) as reported by Wartenberg and Savitz (*29*). Olsen et al. (*15*) compared exposures of all children diagnosed with leukemia, tumors of the central nervous system, or malignant lymphoma from 1968 to 1986. They found a nonsignificant, elevated relative risk for all cancers studied using an *a priori* cutpoint (OR = 1.5 for cutpoint of 0.25 μT) and a statistically significant excess for a higher, *a posteriori* cutpoint (OR = 5.6 for cutpoint of 0.4 μT). Verkasalo et al. (*16*), studying children living within 500 m of a high-voltage transmission line in Finland, found elevated leukemia, nervous system cancers, and overall cancers, with the rate of nervous system cancers being statistically significantly elevated [standardized incidence ratios = 2.3), especially for gliomas (SIR) = 6.5.

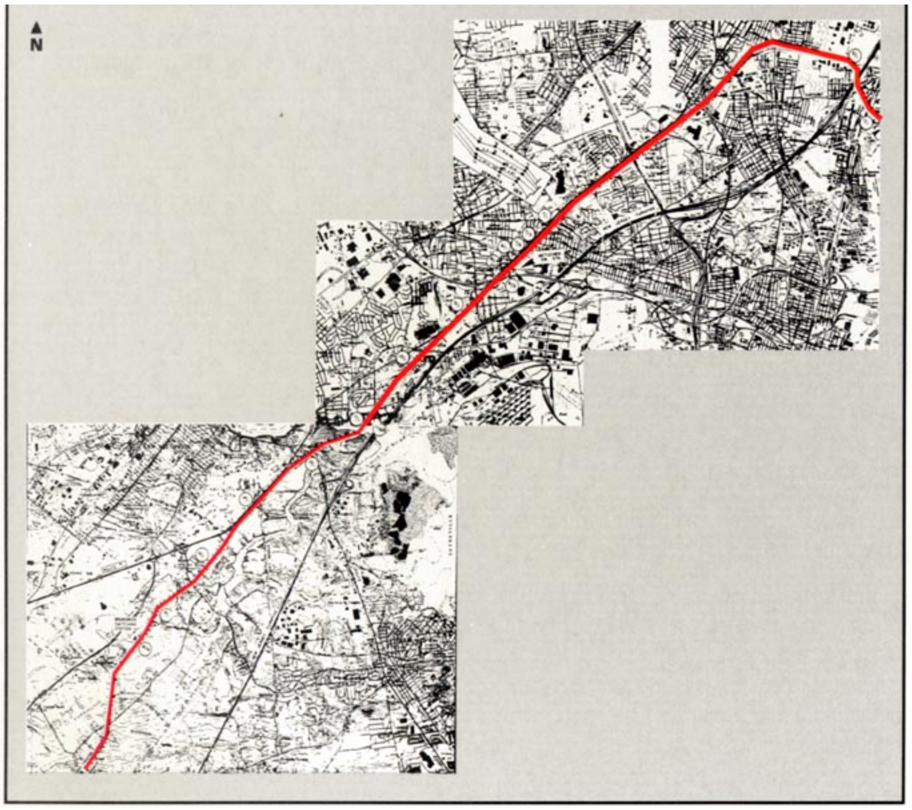

Figure 1. A route map of a 230-kV electric transmission line from Woodbridge, New Jersey to South Brunswick, New Jersey. Note that a USGS quadrangle is used as a base map.

Methods

The basic methodology we used was: 1) select a transmission line, 2) digitize it, 3) superimpose it on the U.S. Census TIGER files, 4) construct a buffer around the line, 5) identify all census blocks contained within or intersecting the buffer, and 6) extract the relevant demographics for these census blocks from the U.S. Census demographic files. We describe this process in more detail below.

To begin our pilot study, we wanted to use a high-voltage transmission line in the vicinity convenient to our research team. After consultation with the local utility, Public Service Electric and Gas, we selected a 29-km segment of a 230-kV line that runs from the Sewaren Switching Station in Woodbridge, New Jersey, to the Deans Switching Station in South Brunswick, New Jersey, circuit S-2219. We note that while this line may not be typical of the United States, it is not atypical of lines in eastern New Jersey, a very densely populated area.

The first step in this procedure was specification of the exact location of each transmission tower. Using a series of maps developed by the utility company (Fig. 1), we digitized the geographic coordinates of each transmission tower in a Universal Transverse Mercator coordinate system and stored the resulting data in a vector digital line graph format.

To locate the line and retrieve demographic data for the populations living near the line, we used the 1990 U.S. Census data. The Census Bureau has released a computerized set of detailed geographic map files known as TIGER (topologically integrated geographic encoding and referencing) files. These files contain details on the physical features and census tract (and block) boundaries for every county in the United States. These data are relatively fine-scaled, particularly in more densely populated areas, and enable researchers to reference these geographic locations to census tract (and block)-level demographic data (*30,31*).

We related the location of the transmission line to the U.S. Census data using the Arc/Info GIS package (Figs. 2 and 3). Then, we specified an arbitrary 100-m buffer zone on either side of the transmission line as the region of concern. The width of this buffer corresponds to a magnetic field exposure of approximately 0.2 μT (See appendix). Some studies have considered even wider buffers [e.g., 200 m (*8*), 300 m (*14*), 500 m (*16*)], but we believed a smaller buffer would provide a more rigorous test of the methodology.

We extracted the block numbers of all intersecting blocks, the total area contained within each census block, and the area of each census block contained within the buffer to enable us to calculate the percentage of each intersecting census block inside the buffer.

To obtain the demographic data for the identified census blocks, we matched the ID numbers for the blocks intersecting or contained within our buffer with the attribute data and extracted the relevant information. For comparison purposes, we also extracted summary data for each town (municipality) in our study. These data were further processed and summarized using our own software.

Results

Overall, we found 201 census blocks that intersected or were contained within a buffer of 100 m on either side of the center line, containing a population of 18,040 individuals and 7,154 housing units. Of these blocks, 21% (42 of 201) had no housing units and hence no population, as reported by the U.S. Census, and 30 blocks had no data reported because the population sizes within these individual blocks were so small that release of block data would have jeopardized individual confidentiality. These blocks represented a total of 2,865 (16%) individuals and 1,161 (16%) housing units. The remaining 129 blocks contain 15,175 individuals and 5,993 housing units. Two of the six towns along the path of the transmission line, New Brunswick and Milltown, did not have any blocks with enumerated populations. They are shown on the figures but omitted from the tables. All further calculations and tabulations in this paper are based on those blocks with fully enumerated data only. The demographics in these blocks were characterized and are summarized in Tables 2 and 3.

Table 2 categorizes the census block data by the proportion of the area of the block contained within the 100-m buffer we defined. The majority of the population identified lives in blocks in which only a small proportion of their area lies within the buffer. It is likely that most of the individuals residing in these blocks live outside the buffer. However, some of the blocks

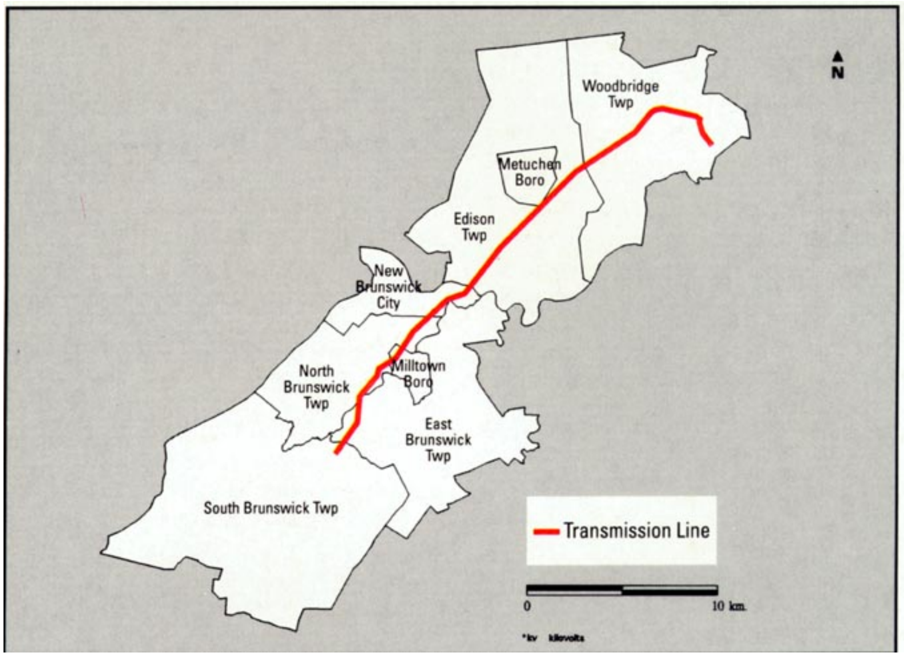

Figure 2. A map of the electric transmission line shown in Figure 1 digitized and superimposed on township boundaries generated using U.S. Census TIGER files.

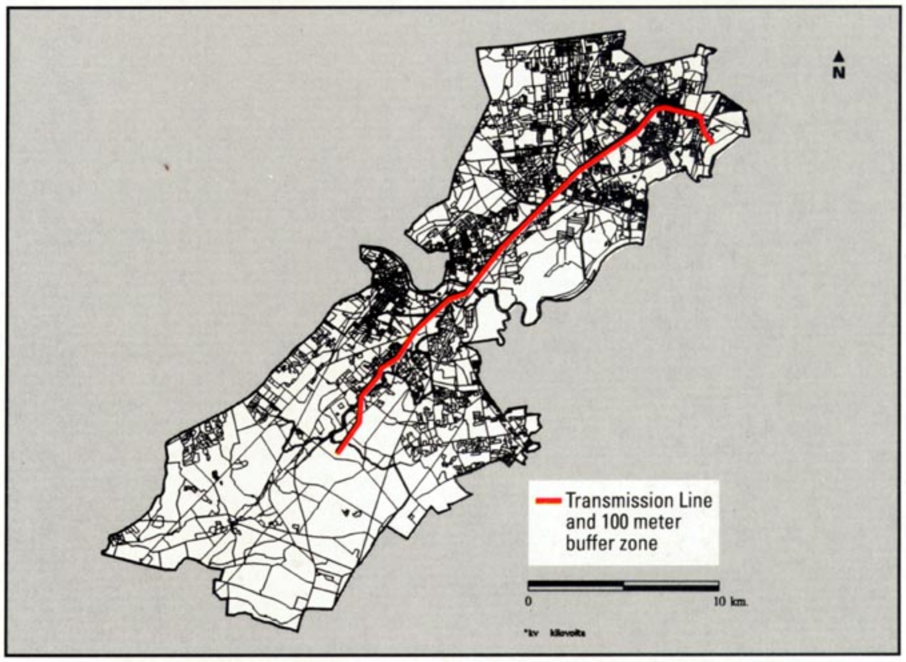

Figure 3. The map and line shown in Figure 1 digitized and superimposed on U.S. Census block boundaries generated from the U.S. Census TIGER files, with a 100-m buffer on either side of the line.

Table 2. Population and housing units with 100-m buffer

% of area of census block[a]	No. of census blocks included (%)	No. of people in census blocks included (%)	No. of houses in census blocks included (%)
100	7 (5.4)	358 (2.4)	183 (3.1)
95	11 (8.5)	530 (3.5)	255 (4.3)
90	12 (9.3)	535 (3.5)	257 (4.3)
70	15 (11.6)	678 (4.5)	311 (5.2)
50	37 (28.7)	2,724 (18.0)	1,128 (18.8)
30	62 (48.1)	6,681 (44.0)	2,977 (49.7)
10	91 (70.5)	11,001 (72.5)	4,447 (74.2)
0[b]	129 (100.0)	15,175 (100.0)	5,993 (100.0)

[a]Within buffer required for inclusion.
[b]All census blocks intersection buffer included.

are wholly contained, or mostly contained, within the buffer. Many of the individuals living in these blocks live within the buffer. Refinement of these data would require field evaluation or analysis of aerial photography to locate individual housing units with respect to the buffer border. We did not undertake such analyses in this study.

Table 3 compares some of the demographic and perceived housing value characteristics of the populations living within the buffer, or near the buffer, with the similar characteristics of the town in which the buffer is contained. In general, demographic values are similar among towns and inside and outside the buffer. For example, for the percentage of the population under age 18, the entire towns show between 19% and 26%, while blocks intersecting or contained within the buffer show between 13% and 25%. Similarly, the percentage of the population over 65 years of age is generally between 6% and 16%, the percent white is generally between 79% and 95%, and the percent black is between 0% and 12%. For these four demographic variables, the average differences among the towns are similar to the average differences between each town and that part of the town contained within the buffer except perhaps for percent white, which shows slightly larger variation within than between towns. Interestingly, the blocks within the buffers tend to have fewer people under 18 years of age, more whites, and fewer blacks.

Variables reflective of perceived housing value, however, differ more greatly within towns than between, as shown by the differences at the bottom of Table 3. Percent owner-occupied varies between 61% and 82% for towns as a whole, while it varies between 60% and 98% for blocks within the buffer. Average housing price varies between $163,400 and $204,500 among towns, while it varies between $127,062 and $274,979 for blocks within the buffer. Average rent varies between $644 and $725 among towns and between $520 and $1175 for blocks within the buffer. One association between the variables is noted: if the percent owner-occupied is greater for blocks within the buffer, so is the cost. In general, except for North Brunswick, rents tend to be lower for blocks inside the buffer.

Only one town, Woodbridge, has a sufficient number of blocks nearly wholly contained within the buffer for evaluation (Table 4). They are listed as those blocks with 90% of their area contained within the buffer. The patterns for these blocks are similar to those described above, with more white and fewer black people, and the average rent being even lower than in all the blocks intersected by the buffer.

Discussion

Previous epidemiologic studies of the association between exposure to magnetic fields and the incidence of cancer sought to quantify a relatively small risk for rare diseases. As such, epidemiologists used a case–control design to identify a population of individuals with the disease of concern and a control population and to characterize their exposures. Because the study subjects were selected on the basis of disease status rather than exposure status, their exposures reflected the most common levels of exposure, mainly those below 0.5 μT. Generally, individual studies compared populations whose mean exposures differed by only a few tenths of a microtesla. Taken as a whole, results of these studies are uncertain, show numerous inconsistencies, and conclusions tend to be controversial.

Given the widespread distribution of electrical distribution systems, there is a substantial number of people with exposures markedly higher than 0.5 μT. Although these individuals represent a small proportion of the entire U.S. population, we believe that they are common enough to represent a useful cohort for epidemiologic study. If there is an association between residential exposure to magnetic fields and cancer, and if the dose–response relationship is monotonic, then studies comparing populations with mean exposures that differ by 1–3 μT should have substantially more statistical power and precision than those comparing populations with mean exposures that differ by 0.1–0.5 μT.

Toward this end, we developed a method for identifying and characterizing these highly exposed individuals. We used a computerized procedure so that large regions can be assessed rapidly and easily and so that populations of sufficient size for epidemiologic study can be readily identified.

In our pilot study in New Jersey, we examined the demographics of the populations living near a single high-voltage transmission line in five towns and compared these data to comparable data for each town as a whole. We found that the

Table 3. Population characteristics by town: overall and within 100-m buffer

Township	No. of blocks	Population	Housing units	% under 18	% over 65	% White	% Black	% Owner occupied	Mean cost ($)	Mean rent ($)
East Brunswick	—	43,548	15,395	24.0	8.7	88.1	2.2	81.7	203,700	725
Blocks intersecting buffer	10	731	248	24.6	10.7	94.1	0.4	90.3	274,979	535
Edison	—	88,680	32,832	21.7	10.7	79.5	5.6	64.7	204,500	659
Blocks intersecting buffer	50	6,436	2678	19.5	9.4	86.1	4.1	62.7	177,405	588
North Brunswick	—	31,287	12,186	20.4	9.2	80.1	11.1	61.2	199,300	681
Blocks intersecting buffer	15	2,003	369	13.3	6.6	86.9	3.9	97.3	268,968	1175
South Brunswick	—	25,792	9,962	25.2	6.5	84.1	6.2	70.5	201,600	724
Blocks intersecting buffer	1	152	55	20.4	15.1	94.7	0.7	81.8	233,400	520
Woodbridge	—	93,086	34,498	19.3	13.0	86.6	6.5	70.7	163,400	644
Blocks intersecting buffer	53	5,853	2643	18.0	13.4	85.8	4.5	60.4	127,062	602
Mean difference among towns				3.1	3.0	4.7	3.7	9.4	17,320	45
Mean difference between town and buffer				3.2	3.0	6.2	3.6	13.7	47,236	200

Table 4. Population characteristics of Woodbridge: overall and within 100-m buffer

	No. of blocks	Population	% under 18	% over 65	% White	% Black	Housing units	% Owner occupied	% Renter Occupied	Mean cost ($)	Mean rent ($)
Town	—	93,086	19.3	13.0	86.6	6.5	34,498	70.7	26.3	163,400	644
Blocks intersecting buffer	53	5,853	18.0	13.4	85.8	4.5	2643	60.4	36.1	127,062	602
Blocks 90% within buffer	9	442	19.5	10.0	96.4	2.9	212	54.3	44.3	146,246	593

population characteristics (e.g., age, ethnicity) did not differ markedly between those close to the lines and those far away, although the perceived housing value variables (e.g., house value, rent, proportion owner-occupied) varied more so. Further, the perceived housing value variables differed not only within a town but also between towns. We note, however, that these observations are likely to be highly unstable due to the very small sample size.

To explain these variations, we visited the area in question. The reasons for the differences, we believe, are town specific. Although the towns are similar in terms of overall demographics and perceived housing value, the areas of the town through which the transmission line runs are different. For example, in one portion of Edison, the line runs along a major local road and borders on a low-income housing project. Thus, it is not surprising that the census blocks within the buffer are more frequently renter occupied and that housing and rental costs are relatively low. In North Brunswick, on the other hand, the transmission line runs through a fairly upscale region, as is reflected in the high owner-occupancy rate and the high rental and housing costs. This suggests that it is probably not possible to generalize about populations that live near high-voltage transmission lines but rather to note that, since all people need electricity, lines run through all towns and through all kinds of neighborhoods.

One interesting observation is that, based on this small and arbitrary sample of data, there is no evidence of environmental disparity with respect to ethnicity or socioeconomic status. That is, in spite of the possible undesirability of proximity to high-voltage transmission lines (for health or aesthetic reasons), we do not see them preferentially located in nonwhite or less affluent regions. Rather, their locations are town dependent. In most of the towns we studied, the populations living closest to the line were more white and had a wider age distribution than the towns that surrounded them. Housing values varied markedly by town, although values within the buffer were lower than the town as a whole more often than not, possibly suggesting a perception of lower value.

Conclusions

Our pilot study had two objectives: to demonstrate the feasibility of identifying populations living near high-voltage transmission lines for epidemiologic study and to characterize these populations. We have shown that we can identify these populations readily using a GIS and the 1990 U.S. Census databases. Although we cannot estimate the distance from the center line for each individual or housing unit, we can provide grouped estimates based on reasonable buffer sizes. Since we assessed the population along only a few miles of a single line in New Jersey and found hundreds of people living within 100 m, we believe that this methodology could be used, at least in New Jersey, to identify a cohort of sufficient size for epidemiologic study. Further, these populations are not different socio-demographically from the rest of the population, making them attractive for epidemiologic study.

In terms of the characteristics of these individuals, our pilot study demonstrates that for a single, arbitrarily chosen 230-kV line in New Jersey, the populations living close to the line have fewer people under age 18, are more white, and have less expensive rents. Housing costs depend more on the communities we examined than on the houses' proximity to the power line. These data support the notion of environmental equity for this potential health hazard in this pilot study area, although further study is warranted.

Appendix

Determining the Magnetic Field Strength at the Edge of the Right-of-Way

To determine the relevance of our arbitrary buffer width, we calculated a sample magnetic field strength at the edge of the buffer. To do so, one needs to know the geometric configuration of the three conductors on the tower, the distance between the conductors, and the current flowing through the line (*17*). Often, along a transmission line, the tower configurations will vary. For these calculations we selected an arbitrary tower to use in our calculations. The three conductors for this line were configured vertically (that is, one was directly above the other, which was directly above the third), and each pair was separated by 21 feet, or 6.4 m (F. Blahuta, personal communication). The normal current load on this line was 953 amps (J. Flynn, personal communication). This is not the maximal load, but rather a typical load used for rough calculations.

To calculate the ambient magnetic field attributable to this line, we used the following formula (*17*):

$$B = \frac{I}{5R^2}\sqrt{\frac{S_{12}^2 + S_{13}^2 + S_{23}^2}{2}}$$

where B is the field's total flux density in microtesla, I is the current in amperes carried by each of the three phase conductors, R is the distance in meters from the line to the point where the field is being calculated, and S_{ij} is the transverse distance in meters between the ith and jth conductors. Therefore,

$$B = \frac{953}{5(100)^2}\sqrt{\frac{(6.4)^2 + (12.8)^2 + (6.4)^2}{2}}$$
$$= 0.21\mu T$$

Thus, the magnetic field attributable to the transmission line at the edge of the buffer was 0.2 μT. At 50 m from the center line, the field would be 0.5 μT. At 25 m from the center line, the field would be 2.1 μT. And, at the center line, the field would be 1315 μT.

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